METHOD, SYSTEM, AND MEDIUM FOR HANDLING MISREPRESENTATIVE METROLOGY DATA WITHIN AN ADVANCED PROCESS CONTROL SYSTEM

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Related Application

This application claims priority from U.S. Provisional Application No. 60/399,695, filed August 1, 2002, which is incorporated herein by reference.

Field of the Invention

The present invention relates to improved feedback controllers designed for manufacturing semiconductor devices. In particular, the feedback controllers of the present invention include features to detect erroneous data points and to prevent those data points from affecting the operation of the feedback controllers.

Background of the Invention

There is a constant drive within the semiconductor industry to increase the quality, reliability and throughput of integrated circuit devices, e.g., microprocessors, memory devices, and the like, while lowering the costs of manufacturing such devices. This drive is, in part, fueled by consumer demands for faster, higher quality computers

and electronic devices at lower prices. These demands have resulted in continual improvements in the manufacturing of semiconductor devices.

In manufacturing semiconductor devices, it is a well-known practice to use feedback controllers to ensure high quality and low cost. An example of a feedback controller system **100**, shown in FIG. 1, includes a tool **103** and a feedback controller **107** coupled each other. The tool **103** can be one or any combination of semiconductor-manufacturing tools such as a chemical mechanical planarization (CMP) tool, a depositor, an etcher, etc. In particular, the tool **103** receives wafers as input **101** and processes them according to a set of control parameters **109**, e.g., recipes received from the controller **107**. The processed wafers are referred to as outputs **105**. Examples of processes are depositing a new layer of film, etching a layer, etc.

Once the tool **103** processes a wafer, one or more metrology stations, not shown in FIG. 1, make measurements on the processed wafer. The measurements are communicated to the controller **107**. The controller **107** then compares the measurements to predicted values calculated previously. Based on the comparison, the controller **107** makes adjustments to the control parameters **109**. For example, if the thickness of a newly deposited layer is outside of a desired range when the measurement is compared with the predicted value, the controller **107** adjusts one or more of the control parameters **109**, e.g., the amount of gas flow, the length of processing time, etc., to deposit a thinner film on the next wafer. The tool **103** then receives another wafer and processes the wafer using the adjusted control parameters.

The performance of the feedback controller depends on, in part, receiving accurate measurements from the metrology stations. When inaccurate or erroneous

measurements are received, the feedback controller needs to identify such measurements and have a mechanism to prevent such measurements from affecting the operation. In conventional feedback controllers, no robust mechanism was provided to address erroneous measurements. When erroneous measurements are entered repeatedly to the controller **107**, they cause increased defects, low yields, or both in devices formed on processed wafers.

Summary of the Invention

Embodiments of the present invention advantageously identify erroneous measurements and prevent the erroneous measurements from being input to a feedback controller. In particular, embodiments of the present invention provide a system, method and medium for initially identifying erroneous data points and preventing them from affecting the operation of the feedback controller. Embodiments of the present invention include features for receiving data points relating to an output of the tool. The data points include a current data point and at least one previous data point. The at least one previous data point is received before the current data point. Embodiments of the present invention also include features for determining whether the current data point is an erroneous outlier by comparing the current data point to a statistical representation of the at least one previous data point, and based on whether the at least one previous data point was also an outlier. Embodiments of the present invention further include features for disregarding the current data point in calculating a feedback value of the feedback control mechanism if the current data point is determined as an erroneous outlier.

Brief Description of the Drawings

The detailed description of the present application showing various distinctive features may be best understood when the detailed description is read in reference to the appended drawing in which:

FIG. 1 is a block diagram illustrating a conventional feedback control system;

FIG. 2 is a graph illustrating an example outlier data point;

FIG. 3 is a graph illustrating an example step change;

FIG. 4 is a block diagram illustrating a feedback controller that includes an optimizer and an estimator according to embodiments of the present invention;

FIG. 5 is a flow chart illustrating high level features of the estimator according to embodiments of the present invention;

FIG. 6 is a flow chart illustrating features of the estimator with respect to determining an outlier according to embodiments of the present invention;

FIG. 7 is a flow chart illustrating features of the estimator with respect to adjusting measurements according to embodiments of the present invention;

FIGs. 8A and 8B are flow charts illustrating features of overall sequence of steps according to embodiments of the present invention;

FIG. 9 is a graph illustrating example measurement values processed according to embodiments of the present invention; and

FIG. 10 is a block diagram representation of a computer within which an example embodiment of the feedback controller can operate according to embodiments of the present invention.

Detailed description

A feedback system for a semiconductor manufacturing tool typically includes a metrology station (which can be internal to or external of the tool) to make measurements on one or more characteristics of outputs (e.g., processed wafers) of the tool and a feedback controller to change the operation of the tool based on data points (where a data point is calculated from or equivalent to one or more measurements of a wafer or wafers). Various embodiments of the present invention relate to feedback controllers that include features for identifying outlier data points (i.e., data points that are substantially different from one or more previous data points), for differentiating the outlier data points into erroneous outlier data points and non-erroneous outlier data points (e.g., outliers representing a change in the status of the tool), and for removing the erroneous data points from affecting the operation of the feedback controller and its tool. These embodiments are illustrated in connection with FIGs. 5-6. As noted above, a data point can be calculated from one or more measurements of a single wafer. These measurements can also contain outliers that are substantially different from other measurements taken from the wafer. In at least some embodiments of the present invention, these outlier measurements are identified and removed before calculating any data points for the wafer. These embodiments are described in connection with FIG. 7. In at least some embodiments of the present invention, portions or all of the features of the above-mentioned embodiments relating to identifying and removing outliers from measurements and data points can be combined into one system. These embodiments are described in connection with FIGs. 8A-8B.

Before various embodiments of the present invention are described, the general concept of outliers is first described in more detail. As noted above, an outlier is a data point that is significantly different from previous data points. The significance of the difference can be measured in terms of statistics, e.g., average, median, standard deviation, etc. An outlier data point may indicate that a change has occurred in the tool and that a response by the feedback controller may be required (e.g., adjusting control parameters). In other instances, an outlier data point may indicate that the measurements made by the metrology station are erroneous (i.e., an erroneous outlier data point). In such a case, the erroneous outlier data point is removed from affecting the operation of the feedback controller. To further explain these concepts, an example of an erroneous outlier is illustrated in FIG. 2, and an outlier data point representing a non-erroneous outlier is illustrated in FIG. 3.

More specifically, in FIG. 2, a black line **201** depicts a trace of differences between data points and their respective predicted values in a sequence of processed wafers. In the present invention, the predicted values are calculated based on, in part, previous data points. In the y-axis, difference values, F(k), of the processed wafers are shown. Processed wafer 20 has its difference value at 1, while wafers 1-19 and 21-40 have their difference values at zero. The data point for wafer 20 depicted in FIG. 2 misrepresents or incorrectly characterizes the processes that took place in the tool because the difference value jumps to 1 for wafer 20 and drops back to zero. It may also represent an error in calculating the data point that was the basis for calculating the difference value. Such a data point is preferably treated as an erroneous input.

Accordingly, it is desirable to prevent such a data point from being input to the feedback controller.

In FIG. 3, a similar change occurs at processed wafer 20, but the difference values stay at 1 for wafers 21-40. In such a case, the difference value for wafer 20 most likely represents the leading edge of a change rather than an erroneous outlier. The change illustrated in FIG. 3 contains relevant information regarding the processes that took place in the tool. Accordingly, it is desirable to input the data point at the leading edge of the change to the feedback controller in order to make appropriate adjustments.

To distinguish erroneous outliers from non-erroneous outliers, embodiments of the present invention include, among other features, a tool **401**, one or more metrology stations **403**, and a feedback controller **406** that includes an estimator **405** and an optimizer **407** as illustrated in FIG. 4. The tool **401** is similar to that described above in connection with FIG. 1. The metrology stations **403** (which can be part of, or external to, tool **401**) are configured to make one or more measurements on the processed wafers. In particular, the measurements can be of different categories, e.g., the thickness of deposited films, various features of transitions, etc. The metrology stations **403** can also make one or more measurements for each category measurement. For instance, the metrology stations **403** can measure the thickness of a wafer at multiple points on a processed wafer.

The values of the measurements made by the metrology stations **403** are communicated to the controller **406**. Upon receiving the measurement values, the estimator **405** calculates one or more data points from the measurements. The estimator

405 is configured to improve prediction capabilities of the controller **406** based on new information, e.g., data points, etc.

Once a data point is calculated, it is processed as shown in FIG. 5. In particular, the estimator **405** determines if the new data point is significantly different from the predicted value, and can thus be considered a "candidate" outlier (step **503**). If so, the data point is designated as a candidate outlier (step **504**). It is called a candidate because whether the outlier is an erroneous data point or a data point representing a change is determined later. If the data point is not a candidate outlier, then the estimator **405** calculates and communicates a feedback value of the data point to the optimizer **407** (step **509**). Here, the feedback value is a value proportional to the difference (if any) between the value of the data point and the predicted value calculated by the controller **406**. The optimizer **407** then uses the feedback value in calculating a new set of control parameters. In embodiments of the present invention, the optimizer **407** is configured to produce control parameters in an optimal way (e.g., minimal changes to the control parameters while meeting all targets in driving the tool to produce desired outputs).

If the data point is a candidate outlier, and the previous data point was not marked as a candidate outlier (as determined by step **505** in processing the previous data point), the data point is most likely an erroneous data point (i.e., an erroneous outlier) similar to the one depicted in FIG. 2. As such, no feedback value is communicated to the optimizer **407** (step **511(a)**). In other words, such a data point is removed from affecting the operation of the optimizer **407**. It follows that if the previous data point is not a candidate outlier, the data point is a candidate, and a subsequent data point is not a candidate, then the data point is an erroneous data point.

In at least some embodiments of the present invention, the estimator **405** determines if two or more previous data points were marked as outliers instead of just one previous data point. In such embodiments, if the two or more previous data points were not marked as outliers, the data point is designated as an erroneous outlier. Once again, no feedback value is communicated to the optimizer **407**. When no feedback value is communicated, the optimizer **407** can use the previous set of control parameters in controlling the tool **401**.

In at least some embodiments, instead of preventing the feedback value of every candidate outlier from being input to the optimizer **407**, a threshold test is first performed. In these embodiments of the present invention, even if the new data point is determined to be a candidate outlier, if the difference between the data point and the predicted value falls below/above the threshold value, then a feedback value is communicated to the optimizer **407** to be used in calculating the control parameters. It should be noted that the threshold can also be a range as well.

If the estimator **405** determines that the previous data point was also an outlier (or a candidate outlier), this condition is similar to the one depicted in FIG. 3 because the change that took place with the previous data point continues in the current data point. In such a case, the feedback value of the previous data point would not have been communicated to the optimizer **407** for the previous data point, when it should have been because it represented a change. Hence, the estimator **405** first calculates the feedback value of the previous data point, and the feedback value of the new data point is then calculated. The latter value is communicated to the optimizer **407** to be used in calculating the control parameters (step **507**).

Although the above description is provided for processing one data point to calculate one feedback value, any number of data points can be used in calculating any number of feedback values. Hence, the optimizer **407** is configured to receive any number of feedback values from the estimator **405**. More specifically, when it receives the feedback values from the estimator **405**, the optimizer **407** calculates a new set of control parameters. In calculating the new set of control parameters, the optimizer **407** may simply make adjustments to the previous set of control parameters based on the feedback values received.

The above-described features of the controller **406** are now described in more detail by referring to FIG. 6. More specifically, in at least some embodiments of the present invention, in order to determine if a data point is a candidate outlier, a statistical filter is used. In at least some embodiments of the present invention, an exponentially-weighted moving average (EWMA) filter is used. In embodiments of the present invention, other types of filters can also be used, e.g., finite-impulse response, infinite-impulse response, or wavelet-based filters. In the following example, the exponentially-weighted moving average for variance of prediction value can be expressed as:

$$S_k = \beta(F_k - \Delta_k)^2 + (1-\beta)S_{k-1}$$

The corresponding value of standard deviation is expressed as:

$$s_k = \sqrt{S_k}$$

where,

1. β is a coefficient used for the EWMA filter;

2. F_k is the difference between the data point and predicted value for wafer *k*, and it can be expressed as $y_{k-1}^{actual} - y_{k-1}^{predicted}$, where

y_{k-1}^{actual} is the actual value measured at time/wafer *k*-1; and

$y_{k-1}^{predicted}$ is the predicted value at time/wafer *k*-1; and

3. Δ_k is a feedback value for time *k*, Δ_k. One example set of equations for calculating a feedback value is as follows:

$$
\begin{aligned}
&if\left|F_k - \Delta_k\right| \leq K_n s_k \\
&\quad \Delta_{k+1} = \lambda_k F_k + (1 - \lambda_k)\Delta_k \\
&else \\
&\quad \Delta_{k+1} = \Delta_k
\end{aligned}
$$

where, λ_k is a coefficient used for the EWMA-based filter, which is optionally a function of time and/or other processing events (the value of λ_k may also be set to be a function of wafer number, distance from target or another type of process related event such as the beginning of a new lot or change in process condition); and

K_n is a value called outlier coefficient, which can be set to a certain value, e.g., 0.1.

As the above equations for the feedback value indicate, the feedback value is updated when the difference between F_k and the feedback value is greater than a specified threshold value, $K_n s_k$. This places a limit on the size of adjustments the optimizer **407** may make.

Using the above-described equations, the step of determining whether the data point is a candidate outlier is described. First, when a data point is received, a moving average and its square-root values are updated (step **601**). Using these values, a threshold test is performed to determine when the data point is a candidate outlier. For instance:

if $(F_k - \Delta_k) \geq Ks_{k-1}$, the data point can be marked as "candidate = 1";

if $(F_k - \Delta_k) \leq -Ks_{k-1}$, the data point is marked as "candidate = -1"; and

in all other cases the data point is marked as "candidate = 0".

In other words, the data point is marked as a candidate outlier if $|F_k - \Delta_k|$ is greater than Ks_{k-1}, and it is not marked as an outlier otherwise. Here, K is set to a certain value, e.g., 3. The actual marking is designated as follows:

"0" if the data point is not a candidate;

"1" if actual value for the data point is significantly higher than predicted value and feed back (a candidate); and

"-1" if actual value for the data point is significantly lower than predicted value and feed back (a candidate).

After determining whether a data point is a candidate or not, the estimator **405** determines a state of the data point. Here, a state indicates whether the previous data point was marked as an outlier (step **603**):

if the data point is not a candidate outlier, the state is set to *'regular'*;

if the data point is a candidate outlier and the previous data point was not marked as an outlier, then the data point is meanwhile regarded as an outlier, and the state is set to *'ignore'*; and

if the data point is a candidate outlier and the previous data point was not marked as an outlier, both points are used for the filter calculations, and the state is set to *'two'*.

The following is a set of pseudo codes that capture the above-described feature of setting the state of the data point:

If candidate == 0

State = 'regular'

*If candidate != 0 and candidate*prev_candidate != 1*

State = 'ignore'

*If candidate != 0 and candidate*prev_candidate == 1*

State = 'two'

capture pos and neg.

Once the state is set as described above, the estimator **405** performs the steps described in connection with FIG. 5 in calculating the feedback value. In addition, the estimator **405** also calculates various values of the exponentially-weighted moving average filter and its variance to be used when the next data point arrives:

If state=='two' and new data point was marked as "-1" or "+1": The following equations calculate the values for the previous and the present data points (steps **605** and **607**) and feedback values.

$$S_{k-1} = \beta(F_{k-1} - \Delta_{k-1})^2 + (1-\beta)S_{k-1}$$

$$S_k = \beta(F_k - \Delta_k)^2 + (1-\beta)S_{k-1}$$

$$s_k = \sqrt{S_k}$$

$$\Delta_k = \lambda_{k-1}F_{k-1} + (1-\lambda_{k-1})\Delta_{k-1}$$

$$\Delta_{k+1} = \lambda_k F_k + (1-\lambda_k)\Delta_k$$

If state=='regular': The following equations calculate the values for the present data points (step **607**) and feedback values.

$$S_k = \beta(F_k - \Delta_k)^2 + (1-\beta)S_{k-1}$$

$$s_k = \sqrt{S_k}$$

$$\begin{aligned} &\mathit{if}\ |F_k - \Delta_k| \geq K_n s_k \\ &\quad \Delta_{k+1} = \lambda_k F_k + (1-\lambda_k)\Delta_k \\ &\mathit{else} \\ &\quad \Delta_{k+1} = \Delta_k \end{aligned}$$

If state=='ignore' (implemented also if no wafer arrived in case of missing data): The previously set values are as indicated below.

$$S_k = S_{k-1}$$

$$s_k = \sqrt{S_k}$$

$$\Delta_{k+1} = \Delta_k$$

Now turning to describe embodiments relating to identifying and removing outlier measurements in calculating data points, the outlier measurements may occur due to problems related to the metrology stations such as misalignment of the measurement coordinates or due to physical phenomena such as the presence of particles. These

problems negatively influence the measurement accuracy. Therefore, it is desirable to identify and remove outlier measurements before they are used in calculating data points. In at least some embodiments of the present invention, measurements and information needed to determine outliers are resource specific. This means the information is retained based upon which specific tool or chamber the wafer was processed. Also, the values for the statistical analysis are advantageously maintained as relative values rather than as absolute values.

In these embodiments, the estimator **405** receives a number of measurements from one or more of metrology stations **403** (step **701**). In particular, the estimator **405** retains sufficient information to determine in which specific tool or chamber the wafer was processed. After receiving the measurements from the metrology stations, the estimator **405** calculates their mean and variance values (step **703**). In particular, the mean and variance are expressed as:

$$M_i = \frac{1}{n_i}\sum_{k=1}^{n_i} x_{ik}$$

$$V_i = \left(\frac{1}{n_i - 1}\right)\sum_{k=1}^{n_i}(x_{ik} - M_i)^2$$

where,

data sets are designated as set j and run/wafer i ;

M_i is the mean; and

V_i is the variance.

The mean and variance values can be calculated using a portion or all of the population of the measurements collected for the run/wafer i. The set i corresponds

to data which is a subset of the total measurements performed, defined as x_{ik} where k= 1, ..., n_i, with n_i being the fraction of the total data collected for the run/wafer i.

Since in most semiconductor manufacturing processes the variation of the metrology scales with the average value, a scaling operation (i.e., dividing the variance by a squared mean) can be performed and stored as a scaled variance, D_i. However, a check is performed before the scaling operation to determine if the mean is too small to perform a scaling operation, e.g., a half of a squared mean value is smaller than the variance (step **705**). If the scaling is performed, a register called "FLAG" is set to one (step **709**). If the scaling is not performed, the "FLAG" register and the scaled variance are set to zero (step **707**). The following is a set of equations describing these features:

$$
\begin{aligned}
&if\ \ (V_i < M_i^2/2)\\
&\quad FLAG = 1\\
&\quad D_{\mathrm{i}} = \frac{V_i}{M_i^2}\\
&else\\
&\quad D_{\mathrm{i}} = 0\\
&\quad FLAG = 0
\end{aligned}
$$

The estimator **405** then calculates a filtered estimate of the D_i and V_i, which are designated as D_{i+1}^f and V_{i+1}^f, respectively (step **711**). One example filter is the EWMA.

$$
\begin{aligned}
&if \;\; i = 1 \\
&\quad D^f_{i+1} = D_i \\
&\quad V^f_{i+1} = V_i \\
&else \\
&\quad D^f_{i+1} = \lambda \cdot \min(D_{i+1}, D_i) + (1-\lambda) \cdot D^f_i \\
&\quad V^f_{i+1} = \lambda \cdot \min(V_{i+1}, V_i) + (1-\lambda) \cdot V^f_i
\end{aligned}
$$

The estimator **405** then calculates the standard deviation, σ_i. This value is calculated in two different ways based on to which value the "FLAG" was set (step **713**).

$$
\begin{aligned}
&if \;\; i = 1 \\
&\quad if \; FLAG = 1 \\
&\qquad \sigma_i = \sqrt{D_i} \\
&\quad else \\
&\qquad \sigma_i = \sqrt{V_i} \\
&else \\
&\quad if \; FLAG = 1 \\
&\qquad \sigma_i = \sqrt{\tilde{D}_i} \\
&\quad else \\
&\qquad \sigma_i = \sqrt{\tilde{V}_i}
\end{aligned}
$$

The estimator **405**, which receives a reliability level from a user (step **715**), calculates a sigma coefficient K_f, based on the reliability level. The estimator **405** also calculates the median, R_{ji}, of the measurement values (step **717**). Using the median, R_{ji}, for run/wafer i data set j, the sigma coefficient K_f, and the filtered estimate of the standard deviation σ_i, the estimator **405** calculates an interval (step **719**). An example of the interval can be expressed as:

$$
\begin{aligned}
&if \;\; FLAG = 1 \\
&\quad R_{ji} - K_f \sigma_i R_{ji} \;\; \le x_{ki} \;\; \le R_{ji} + K_f \sigma_i R_{ji} \\
&else \\
&\quad R_{ji} - K_f \sigma_i \;\; \le x_{ki} \;\; \le R_{ji} + K_f \sigma_i
\end{aligned}
$$

The estimator **405** calculates the average of the set of measurement values that fall within the interval (step **721**). The estimator **405** replaces all measurements in set *j* that lie outside the interval with the average value, and sets these points to be outliers (step **723**). The estimator **405** then recalculates and stores the filtered estimate values (step **725**). The value of λ is configurable in a graphical user interface.

Although embodiments described above in connection with FIG. 7 have been separately described from the embodiments describe above in connection with FIGs. 5-6, it should be noted that features of these embodiments can be combined. For instance, when one or more metrology stations make a number of measurements on a processed wafer, these measurements can first undergo the calculations as illustrated in FIG. 7. Subsequently, the calculated averages are designated as data points, and then can undergo the processes as illustrated in FIGs. 5-6. Example embodiments of the present invention that combine the features mentioned above are described below in connection with FIGs. 8A and 8B.

As illustrated in FIG. 8A, measurements that include the value of goodness-of-fit (GOF) are received from the metrology stations **403** (step **801**). The estimator **405** conducts a measurement outlier screening (step **803**). This step is similar to the steps

described above in connection with calculating an interval for the measurements; however, in these embodiments, the GOF and statistical outlier limits for specifically controlled output are provided from memory (**805**). If all measurements are outside the interval, then the measurements are not used in calculating a feedback value (step **809**). If all measurements are not outside the interval, then the estimator **405** calculates the average value of the measurements that fall within the interval (step **811**). The estimator **405** then updates statistical information (step **813**), which can then be stored as an array of statistical information for specific controlled output from previous runs (step **815**).

The average value calculated in step **811** is used as a data point. The estimator **405** performs a data point outlier screen step, which determines whether the data point is a candidate outlier similar to the steps described above in connection with FIGs. 5-6. Based on step **817**, the estimator **405** determines if the data point is an outlier. If it is an outlier, then the data point is not used in calculating a feedback value (step **825**). A state of the data point is determined similar to the steps described above in connection with steps **603**, **605** and **607** (step **821**). The estimator **405** stores the current state of the data point (step **823**). If the data point is not an outlier, the estimator **405** performs a feedback value screening (step **827**), which is similar to the threshold test described above in connection with FIGs. 5-6. Based on the feedback value screening, the estimator **405** determines whether the feedback value is within noise limits (step **829**). If the feedback value is within the noise limits, then the feedback value is not communicated to the optimizer **407** (step **831**). Otherwise, the feedback value is communicated to the optimizer (step **833**). Regardless of whether the feedback value falls within the noise limits, the estimator updates statistical information of relating to the data point (step **835**).

The resulting values are stored as statistical information for specific controlled output from previous runs to be used in performing the feedback outlier screening (step **837**) and noise screening steps (step **839**).

The results of performing the above-described embodiments of the present invention are graphically illustrated in FIG. 9. In particular, each data point represents a wafer being processed by Chemical Vapor Deposition (CVD). A metrology station collects thickness measurements of the processed wafers. For the measurements within normal operation, the average values of the measurements are used as the data points. When the measurements are out of range **907** (e.g., above a threshold value set to detect catastrophic cases), then the tool is halted and a message (e.g., an e-mail message and/or page) is sent to an operator. Moreover, such a set of measurements is not used in calculating a feedback value. When one of the measurements is out of an interval (e.g., **905**), then the measurement is replaced with the average of the measurements within the interval and the filter values are stored.

Embodiments of the present invention can be implemented as a set of computer executable codes (e.g., computer programs), implemented using computer hardware, or any combination of them. In particular, embodiments of the present invention are described in terms of various flow charts as shown in FIGs. 5-8A, B. Various acts depicted in the flow charts can be implemented as codes in computer programs or using computer hardware.

Now turning to describe the software implemented embodiments of the present invention, FIG. 10 illustrates a block diagram of such embodiments. A bus **1056** serves

as the main information highway interconnecting various components. CPU **1058** is the central processing unit, performing calculations and logic operations required to execute the processes of the present invention as well as other programs. Read only memory (ROM) **1060** and random access memory (RAM) **1062** constitute the main memory. Disk controller **1064** interfaces one or more disk drives to the system bus **1056**. These disk drives are, for example, floppy disk drives **1070**, or CD ROM or DVD (digital video disks) drives **1066**, or internal or external hard drives **1068**. These various disk drives and disk controllers are optional devices.

A display interface **1072** interfaces display **1048** and permits information from the bus **1056** to be displayed on display **1048.** Communications with external devices such as the other components of the system described above, occur utilizing, for example, communication port **1074**. Optical fibers and/or electrical cables and/or conductors and/or optical communication (e.g., infrared, and the like) and/or wireless communication (e.g., radio frequency (RF), and the like) can be used as the transport medium between the external devices and communication port **1074**. Peripheral interface **1054** interfaces the keyboard **1050** and mouse **1052**, permitting input data to be transmitted to bus **1056**. In addition to these components, the analyzer also optionally includes an infrared transmitter and/or infrared receiver. Infrared transmitters are optionally utilized when the computer system is used in conjunction with one or more of the processing components/stations that transmits/receives data via infrared signal transmission. Instead of utilizing an infrared transmitter or infrared receiver, the computer system may also optionally use a low power radio transmitter **1080** and/or a low power radio receiver **1082**. The low power radio transmitter transmits the signal for reception by components

of the production process, and receives signals from the components via the low power radio receiver. The low power radio transmitter and/or receiver are standard devices in the industry.

Although the embodiments depicted in FIG. 10 are illustrated having a single processor, a single hard disk drive and a single local memory, the analyzer is optionally suitably equipped with any multitude or combination of processors or storage devices. For example, the various embodiments may be replaced by, or combined with, any suitable processing system operative in accordance with the principles of embodiments of the present invention, including sophisticated calculators, and hand-held, laptop/notebook, mini, mainframe and super computers, as well as processing system network combinations of the same.

Computer readable memory medium stores computer readable code or instructions. As one example, the medium may be used with disk drives illustrated in FIG. 10. Typically, memory media such as a CD ROM, a digital video disk, or floppy disks will contain, for example, a multi-byte locale for a single byte language and the program information for controlling the modeler to enable the computer to perform the functions described herein. Alternatively, ROM **1060** and/or RAM **1062** illustrated in FIG. 10 can also be used to store the program information that is used to instruct the central processing unit **1058** to perform the operations associated with various automated processes of the present invention. Other examples of suitable computer readable media for storing information include magnetic, electronic, or optical (including holographic) storage, some combination thereof, etc.

In general, it should be emphasized that the various components of embodiments of the present invention can be implemented in hardware, software or a combination thereof. In such embodiments, the various components and steps would be implemented in hardware and/or software to perform the functions of embodiments of the present invention. Any presently available or future developed computer software language and/or hardware components can be employed in such embodiments of the present invention. For example, at least some of the functionality mentioned above could be implemented using Visual Basic, C, C++, or any computer language appropriate in view of the processor(s) being used. It could also be written in an interpretive environment such as Java and transported to multiple destinations to various users.

The many features and advantages of embodiments of the present invention are apparent from the detailed specification, and thus, it is intended by the appended claims to cover all such features and advantages of the invention, which fall within the true spirit, and scope of the invention. Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.